Continuous Intervertebral Kinematics Indicate Aberrant Motion Patterns in Lumbar Degenerative Spondylolisthesis

Bryan Rynearson[1], Malcolm Dombrowski[1], Clarissa LeVasseur[1], Zach Adgate[1], William F. Donaldson[1], Joon Lee[1], Ameet Aiyangar[1,2] and William Anderst[1]
[1]Biodynamics Lab, Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, PA, USA
[2]Swiss Federal Laboratories for Materials Science and Technology, Dubendorf, Switzerland
Biodynamics Lab website: bdl.pitt.edu

Introduction

Background

- Lumbar degenerative spondylolisthesis (DS) is an indication for decompression and fusion and is accepted by many as the standard of surgical care[1-3].
- However, growing evidence suggests decompression alone could achieve equivalent clinical outcomes for a subset of patients[4-6]. The diagnosis and surveillance of DS is performed by measuring anterior-posterior (AP) vertebral translation on static flexion-extension lateral radiographs[7-9].
- It is thought that anterior translation increases with flexion and decreases with extension of the spine.
- Inverse patterns have also been described, suggesting kinematic subtypes of DS may exist[10].
- Clinical measurement relies on static end-range images that are subject to significant measurement error[11] and preclude analysis of dynamic mid range motion.

Aim

- To determine if DS kinematics exhibit a single characteristic pattern of rotation and translation during dynamic flexion, and if this pattern differs from asymptomatic controls.

Hypotheses

- In-vivo dynamic imaging will reveal aberrant kinematic motion in patients with DS.

Methods

Subjects

- Six patients with symptomatic L3/L4 (1) or L4/L5 (5) lumbar DS (5 M, 1 F; age 65±5.2 years) and 6 age-matched asymptomatic controls (4M, 2 F; age 62±6.7 years), provided written informed consent to participate in this IRB approved study.

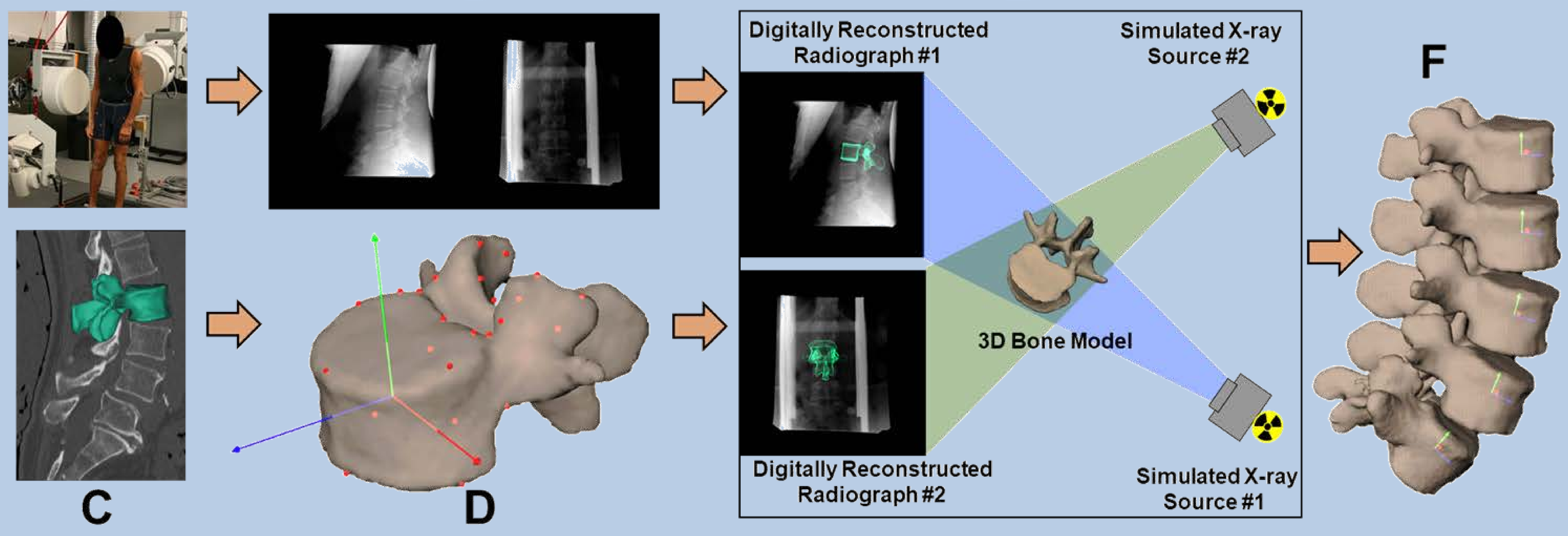

Figure 1. *Data Collection and Processing.*

Data Collection and Processing

- Participants were imaged (L1-S1) in the static upright position (Figure 1A) over 2 flexion/extension trials with a biplane radiographic imaging system at 20 images/s (4 ms pulsed exposures, 70-85 kV, 320 mA) (Figure 1B).
- High resolution computed tomography (CT) scans (Figure 1C) (0.5 mm x 0.5 mm x 1.25 mm) were used to make subject-specific bone models (Mimics 14.0) with anatomic coordinate systems defined in each vertebra (Figure 1D).
- 3D kinematics were determined using a previously validated volumetric model-based tracking process to each vertebra of interest in the radiographic images (precision of 0.26° in rotation and 0.2 mm in translation)[12] (Figure 1E).
- Intervertebral sagittal rotation (flexion/extension) and AP translation (slip) were calculated in the static images and over the entire dynamic torso flexion[13].
- Torso flexion was determined using traditional motion capture techniques with markers placed on the head and torso (Vicon Vantage).

Results

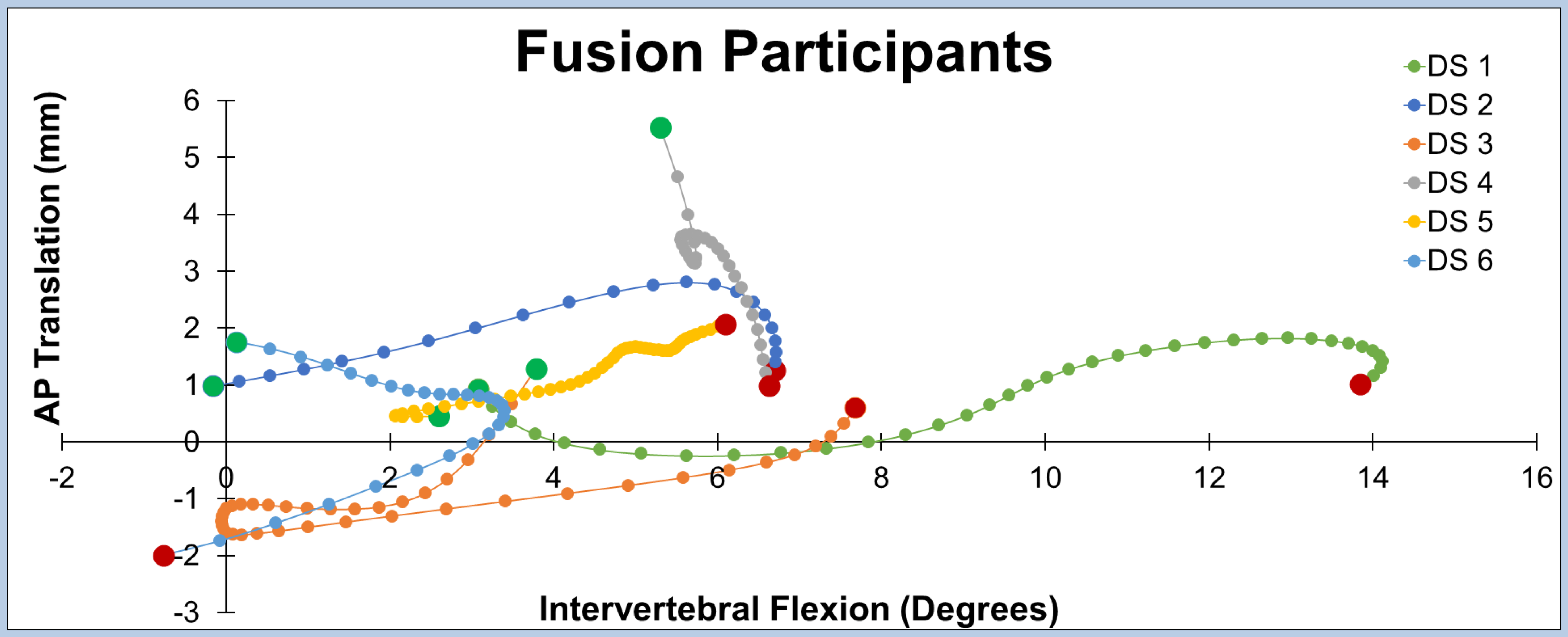

Figure 2. In-vivo kinematics during torso flexion in DS patients. *Green dots indicate start of data collection, red dots indicated full flexion. Only one patient (DS 5) demonstrated a "typical" slip pattern whereby anterior translation was notably increased at end flexion. Three of the remaining five DS patients (DS 1, 2, & 3) demonstrated an appreciable change in AP translation during the midrange of torso flexion, but had virtually the same magnitude of translation by end flexion. One of those three patients (DS 3) exhibited reversal of rotation during the midpoint of torso flexion. For the final two DS patients (DS 4 & 6) slip decreased steadily throughout torso flexion.*

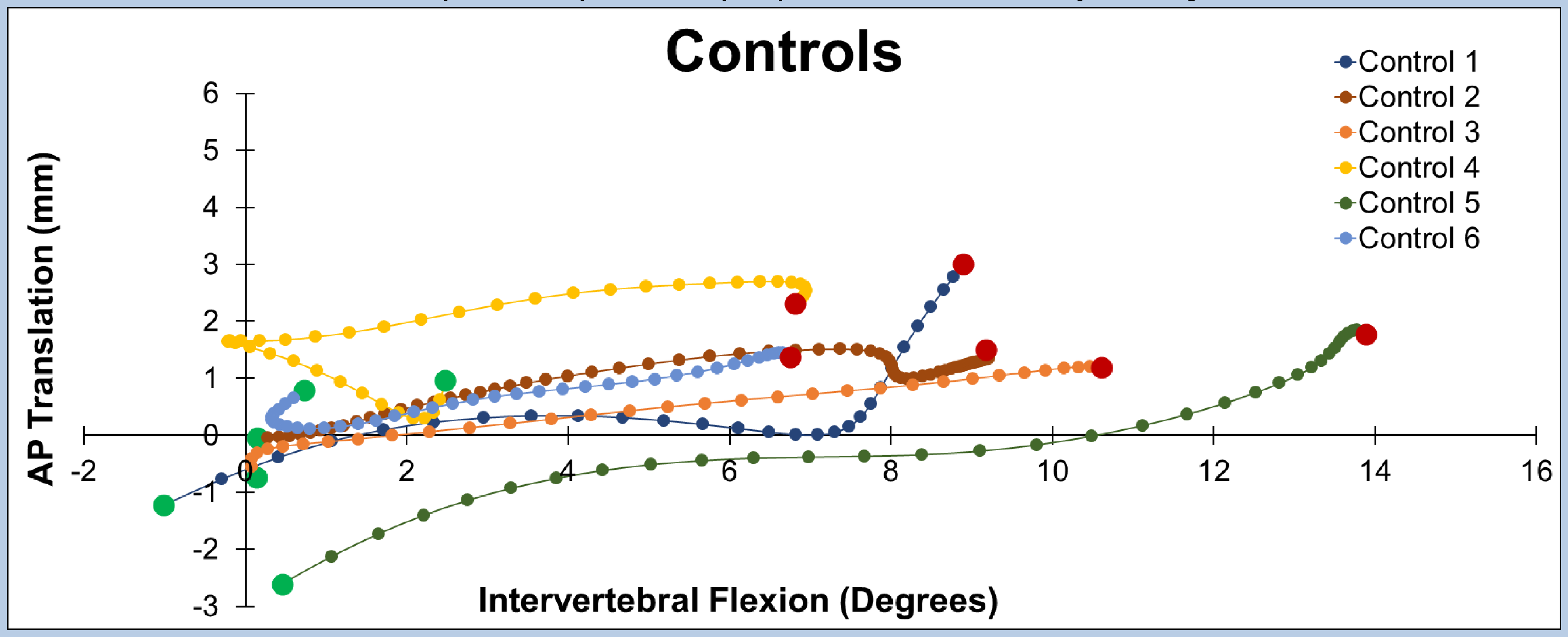

Figure 3. In-vivo kinematics during torso flexion in age-matched controls. *All 6 controls demonstrated a consistent increase in AP translation throughout torso flexion.*

Discussion

- Our data suggests instability associated with DS leads to aberrant kinematics during dynamic torso flexion.
- The majority of DS patients demonstrated what would be generally considered an atypical AP translation pattern during mid-range flexion.
- DS may be better viewed as a spectrum of aberrant motion rather than a single kinematic entity. Further studies with larger patient populations are necessary to further explore this phenomenon.
- We believe this is the first study of its kind to successfully identify continuous mid-range kinematic patterns in DS patients *in vivo*.

Clinical Significance

- Dynamic motion patterns in DS may be used to differentially diagnose patients who are stable through the mid-range of flexion and therefore more likely to achieve successful clinical outcome with decompression alone.

References and Acknowledgement

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